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Enclosed herewith for filing is a patent application, as follows:

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Title: Method and Apparatus For Improved Performance of Flash Memory Cell Devices

X Return Receipt Postcard
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8 page(s) Specification (not including claims)
3 page(s) Claims
1 page Abstract
1 Sheet(s) of Drawings
3 page(s) Declaration For Patent Application and Power of Attorney
1 page(s) Recordation Form Cover Sheet (in duplicate)
2 page(s) Assignment

CLAIMS AS FILED

For	Number Filed		Number Extra		Rate		Basic Fee
Total Claims	12	-20 =	0	x	\$18.00	=	\$ 0.00
Independent Claims	3	-3 =	0	x	\$78.00	=	\$ 0.00
<input type="checkbox"/>	Application contains one or more multiple dependent claims (total fee)						\$
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METHOD AND APPARATUS FOR IMPROVED PERFORMANCE OF FLASH
MEMORY CELL DEVICES

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FIELD OF THE INVENTION

The present invention relates to flash memory or
10 EEPROM memory cells using isolated gate floating gates.

BACKGROUND OF THE INVENTION

Flash memory cell arrays using isolated gate
floating gate MOSFET transistors store charge on the
15 floating gates which modify the threshold voltage (" V_t ")
of the MOSFETs of the memory cells. These memory cells
can be arranged in a NAND gate or NOR gate architecture
for purposes of reading and writing the respective
cells in the array.

20 To achieve higher density, the feature size of
these cells is currently at a low sub-micron level. As
the channels of these transistors become shorter, a
number of detrimental short channel effects are seen.
One solution to avoid these effects, such as "punch-
25 through", is to reduce the dopant levels of the source
and drain of the MOS devices. Reducing source and
drain dopant levels, however, cause an increase in the
series resistance of a memory cell device, thus
reducing the read current to an unacceptably low level.

30 There is thus a need for a method and an apparatus
that maintain a sufficiently high read current in a
floating gate MOSFET transistor, even with a reduced
source and drain dopant levels. In the past,
retrograde doping distribution are created by ion

implantation and subsequent annealing to modify the underlying p-type or n-type well dopant concentration. Such a process is described in Yang, Microelectronic Devices, McGraw-Hill, 1988, and United States Patent
5 No. 5,045,898, issued to Chen et al. on August 30, 1991, entitled CMOS INTEGRATED CIRCUIT HAVING IMPROVED ISOLATION, and United States Patent No. 5,091,332, issued to Bohr et al. on February 25, 1992, entitled SEMICONDUCTOR FIELD OXIDATION PROCESS, the disclosures
10 of which are hereby incorporated by reference. Retrograde dopant distribution in the channel region has also been used to create buried n-channel devices (PMOS) to deal with short channel effects, as is shown in United States Patent No. 5,122,474, issued to
15 Harrington III on June 16, 1992, entitled METHOD OF FABRICATING A CMOS IC WITH REDUCED SUSCEPTIBILITY TO PMOS PUNCHTHROUGH, the disclosure of which is hereby incorporated by reference.

Other methods addressing punch-through and other
20 short-channel effects have included buried back gates, as shown in United States Patent No. 5,877,049, issued to Liu et al. on March 2, 1999, entitled METHOD FOR FORMING ADVANCED TRANSISTOR STRUCTURES WITH OPTIMUM SHORT CHANNEL CONTROLS FOR HIGH DENSITY HIGH
25 PERFORMANCE INTEGRATED CIRCUITS, the disclosure of which is hereby incorporated by reference.

SUMMARY OF THE INVENTION

The present invention relates to providing dopant
30 in the channel area of a well structure for NAND type memory cells formed by isolated gate floating gate transistors. The dopant is provided by ion implantation with a tilt angle around the existing floating gate structure at a selected stage of the

fabrication process following the formation of the control/floating gate structure. The process of the present invention may occur before or after the implantation of the source and drain dopants. The tilt angle implantation forms a retrograde distribution from the channel surface, which is also concentrated laterally toward the centerline axis of the gate structure and decreases towards the opposing source and drain regions. This retrograde distribution promotes buried-channel-like performance of the transistors connected in series in the NAND gate memory architecture and reduces series resistance of the series-connected floating gate MOS devices. Consequently, a reduction in source/drain dopant levels is achieved. Decreasing the series resistance in the bit line provides higher the output current that is available for sensing for a given selected V_{cc} .

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 shows a schematic diagram of a portion of a basic flash memory cell arrangement in a NAND gate architecture; and,

Fig. 2 shows a cross-sectional view of the isolated gate floating gate NMOS transistors forming the NAND gate architecture shown in Fig. 1, at an intermediate stage of manufacture.

The use of similar reference numerals in different Figures indicates similar or identical items.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 shows a schematic view of a portion of a basic flash memory cell arrangement 10 in a NAND gate architecture. Arrangement 10 includes isolated gate floating gate MOSFET transistors 14, 16, 20 and 22

connected together in series by common source/drain leads along a bit line of a memory cell array (not shown).

In the NAND gate architecture, a number of memory
 5 transistors ("cells"), usually a multiple of 8, are
 connected along a "bit line" of a memory array. Each
 of transistors 14, 16, 20 and 22 is associated
 respectively with a word line. For example, the gate
 of transistor 14 is connected to WL0, the gate of
 10 transistor 16 is connected to WL1, the gate of
 transistor 20 is connected to WLn-1, and the gate of
 transistor 22 is connected to WLn.

As shown in Fig. 1, the drain of transistor 14 is
 connected to the source of an insulated gate NMOS
 15 selection transistor 12. The drain of transistor 12 is
 connected to a voltage source V_{cc} and the gate of
 transistor 12 is connected to receive a signal SD. At
 the opposite end of arrangement 10 is provided another
 insulated gate NMOS selection transistor 24. The drain
 20 of transistor 24 is connected to the source of
 transistor 22 and the source of transistor 24 is
 connected to ground. The gate of transistor 24 is
 connected to the source of a signal SS. Together
 transistors 12 and 24 select for reading the stored
 25 content of one of memory transistors 14, 16, 20, 22
 when an associated one of the word lines WL0-WLn is
 selected.

Fig. 2 shows a cross sectional view of a plurality
 of memory cells of arrangement 10 at an intermediate
 30 stage of manufacture. NMOS transistors 12, 14, 16 and
 18 are depicted as being formed in a p-type well 32 of
 n-type mono-crystalline semiconductor substrate 30.
 Source/drain regions 60, 62, 64 and 66, interconnect
 the devices 12, 14, 16 and 18 in series along the bit

line. The source/drain regions 40, 60, 62, 64 and 66 are doped with a relatively light concentration of n-type dopant, indicated by "n".

In one embodiment, select transistor 12 has an
 5 amorphous poly-silicon ("poly") gate 44s (formed as further explained below) and separated from a channel region 70 between drain region 40 and source region 60 by an oxide layer 50 which may be, for example, 168 Å thick. Select transistor 12's poly gate 44s is covered
 10 by a thin tungsten silicide layer 58.

Oxide layer 50 may be thermally grown using a dry oxidation process at about 1050° C. to a thickness of about 148 Å. A photoresist mask is then used to pattern for an etching step that exposes the substrate
 15 outside of the select transistors (e.g., select transistor 12). Then, a film of about 87 Å of oxide is formed as tunnel oxide 52 using a dry thermal oxidation process at about 1050° C. Due to the slower growth rate on oxide layer 50, oxide layer 50 only increases
 20 about 20 Å to a thickness of about 168 Å.

A polysilicon layer 56 is then deposited as a doped amorphous polysilicon layer using an in situ chemical vapor deposition ("CVD") technique which reacts silane (SiH_4) at around 530°C and 400 mT.
 25 Polysilicon layer 56, which subsequently provides floating gates 56m1, 56m2, 56m3, is insulated from the channel regions 72, 74, 76, respectively, by tunnel oxide layer 52. An oxide-nitride-oxide ("ONO") tri-layer 54, for subsequently providing insulators 54m1, 54m2, 54m3 of transistors 14, 16 and 18, is formed by a
 30 first HTO oxide deposition of about 50 Å of oxide at 750°C, followed by deposition at about 760°C of a nitride (Si_3N_4) layer of 80 Å, and a wet thermal nitride oxidation at about 950°C by wet O_2 , thus forming

an oxide layer of about 45 Å thick.

Phosphorous doped polysilicon of about 1200 Å thick is then deposited, using silane at about 530°C and at about 400 mT of pressure, for subsequently

5 forming control gates 44s, 44m1, 44m2, 44m3 of transistors 12, 14, 16, and 18. A 1400 Å tungsten silicide (Wsix) layer 58, for subsequently forming tungsten silicide layers 58s, 58m1, 58m2, 58m3 of transistors 12, 14 and 18, is then deposited by CVD

10 using a mixture of WF₆ gas and silane gas. Patterning using photoresist and subsequent etching steps provide control gates 44s, 44m1, 44m2, 44m3, ONO structures 52m1, 52m2 and 52m3, and floating gates 56m1, 56m2 and 56m3 for the transistors shown.

15 A retrograde distribution of dopant is then introduced by ion implantation into the channel regions 72, 74 and 76, while channel region 70 under select transistor 12 is masked by photoresist. The retrograde distribution of dopant is accomplished by implanting an

20 n-type dopant (e.g., arsenic) at a tilt implant angle of, for example, 45° to vertical. Other tilt angles may also be suitable. The implantation can be made with a "batch-type" machine or with a single-wafer machine. In a batch-type machine, the wafer is rotated

25 during the tilt implantation process. In a single-wafer machine, the implantation is done with a zero degree twist and a 180 degree twist (i.e., an tilt implantation through one side of source/drain regions 60, 62, and 64, followed by a like tilt angle

30 implantation deposition through the source/drain regions 62, 64 and 66). Implantation energies between 80 and 110 KeV are suitable, forming resulting dopant concentrations of about 2×10^{-12} to 8×10^{-13} atoms per cm².

In a batch-type machine, the resulting dopant concentration is generally a frusto-conical distribution at region 80 axially displaced about a target area in the p-type well 32 beneath channel regions 72, 74, 76. In a single-wafer machine, region 80 extends in the channel region parallel to the bit line on each side of the centerline of each channel. After an annealing step, region 80 has a dopant distribution that increases from the level in the substrate closest to the tunnel oxide 52 to the level of the target area and then decreases down through the substrate. In addition, region 80 has a lateral distribution which tends to be highest toward the centerline axis around the target area, and decreases in the direction toward opposing source/drain regions (e.g., source/drain regions 60 and 62 for transistor 14, source/drain regions 62 and 64 for transistor 16).

The retrograde dopant distribution in the channel provides additional carriers (e.g., electrons in the case of an NMOS device) in the channel and decreases the series channel resistance, so that transistors 14, 16 and 18 operate in a manner similar to NMOS buried channel devices.

The present invention has been described in general terms to allow those skilled in the art to understand and utilize the invention, and in relation to a specific embodiment. The present invention is not limited to the preferred embodiment, and may be modified in a number of ways within the scope of the present invention. For example the specific materials and layers of the gate structures of the isolated gate floating gate MOS transistors may be modified. Other dopants may be added to modify the profiles and concentrations of the source/drain regions and the p-

well in addition to those described herein.

Claims

We claim:

- 5 1. A memory array comprising a plurality of floating gate transistors connected in series, each floating gate transistor having formed, in a well of a substrate, a source and a drain region and a channel region separating said source and drain regions, said
10 channel region having a non-uniform concentration of dopant.
2. The memory array of claim 1, wherein said non-uniform concentration comprises a retrograde
15 concentration distribution in the direction from the surface of the substrate.
3. The memory array of claim 2, wherein said non-uniform concentration comprises a lateral concentration
20 distribution along the length of the channel that is higher in a region generally towards the central portion of the channel region and decreases toward the opposing source and drain regions.
- 25 4. The memory array of claim 1 wherein the non-uniform concentration is formed by a tilted ion implantation utilizing as a mask a gate structure of each floating gate NMOS transistor.
- 30 5. A method for making a memory array comprising:
 forming a plurality of floating gate NMOS transistors connected in series, each having a source and a drain region and a channel region separating the source and the drain regions, and

implanting beneath a central portion of the channel region a non-uniform concentration of dopant.

6. The method of claim 5, wherein said non-uniform
5 concentration comprises a retrograde concentration distribution in the direction away from the surface of the substrate.

7. The method of claim 6, wherein said non-uniform
10 concentration comprises a lateral distribution along the length of the channel region that is higher in a region generally towards the central portion of the channel region and decreases toward the opposing source and drain regions.

8. The method of claim 5, wherein said non-uniform
15 concentration is provided by a tilted ion implantation utilizing as a mask a gate structure of each floating gate transistor.

9. An isolated gate floating gate NMOS transistor
20 comprising, in a well structure of a substrate, a source and a drain region and a channel region separating the source and the drain region, said
25 channel region having a non-uniform concentration of dopant.

10. The transistor of claim 9, wherein said non-uniform concentration comprises a retrograde
30 concentration distribution in the direction away from the surface of the substrate.

11. The transistor of claim 10, wherein said non-uniform concentration comprises a lateral concentration

distribution along the length of the channel that is higher in a region generally towards the central portion of the channel region and decreases toward the opposing source and drain regions.

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12. The transistor of claim 9 wherein said non-uniform distribution is provided by a tilted ion implantation utilizing as a mask at least part of a gate structure of said transistor.

METHOD AND APPARATUS FOR IMPROVED PERFORMANCE OF FLASH
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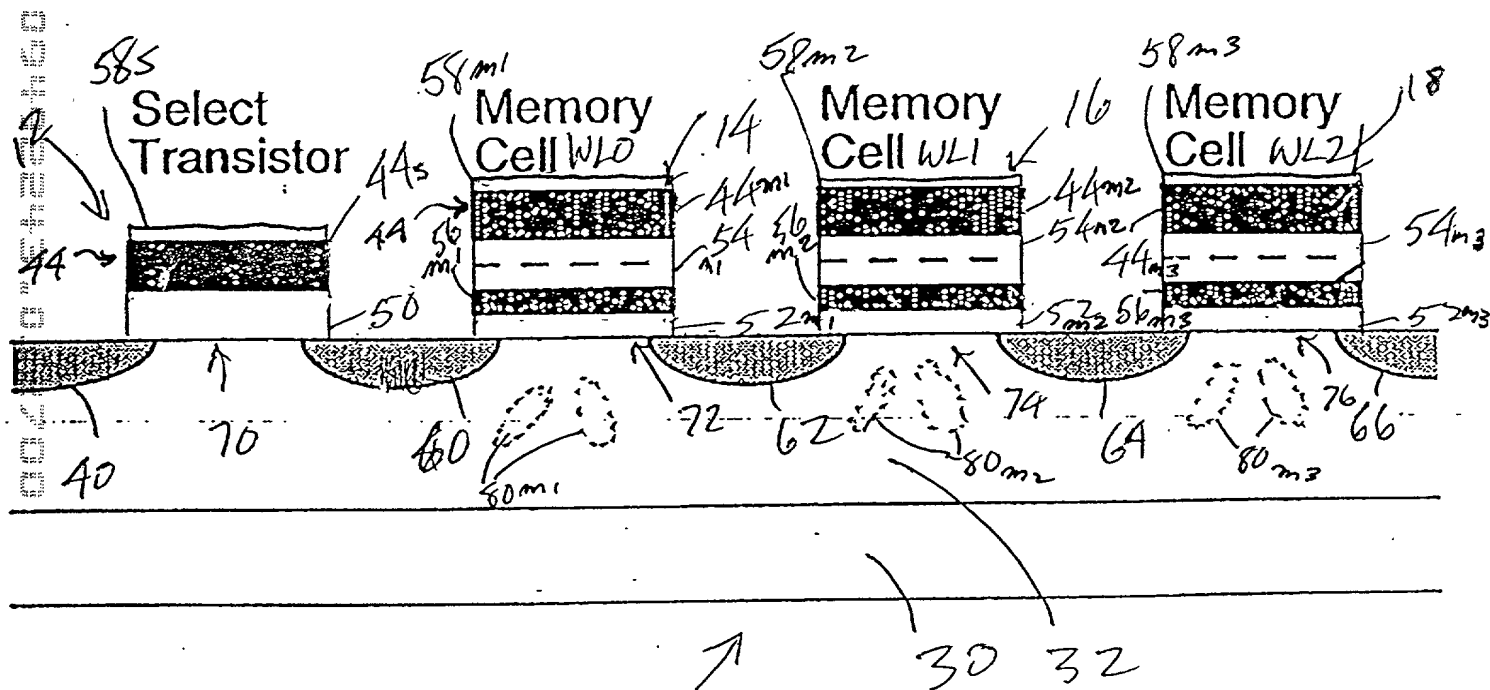
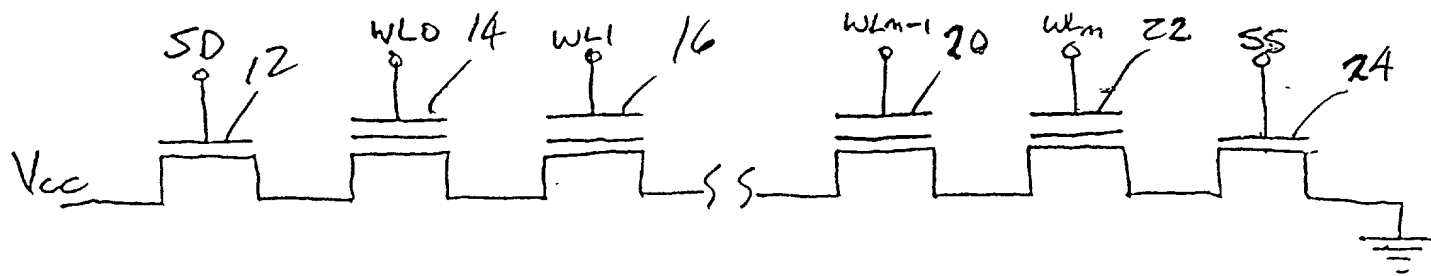
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ABSTRACT

Dopant of an n-type is deposited in the channel
10 area of a p-type well of isolated gate floating gate
NMOS transistors forming the memory cells of a memory
device array connected in a NAND gate architecture.
The dopant is provided by a tilt angle around the
existing floating gate/control gate structure at the
15 stage of the fabrication process where the floating
gate/control structure is in existence, the field
oxidation step may also have occurred, and implantation
of the source and drain dopants may also have occurred.
This forms a retrograde n-type distribution away from
20 the direction of the surface of the substrate in the
channel, which is also concentrated laterally toward
the centerline axis of the gate structure and decreases
towards the opposing source and drain regions. This
deposition promotes buried-channel-like performance of
25 the NMOS transistors connected in series in the NAND
gate memory architecture. This reduces series
resistance of the series-connected floating gate MOS
devices, allowing the desired reduction in source/drain
dopant levels in order to combat short channel effects.

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DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below adjacent to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of subject matter (process, machine, manufacture, or composition of matter, or an improvement thereof) which is claimed and for which a patent is sought by way of the application entitled

Method and Apparatus for Improved Performance of Flash Memory Cell Devices

which (check) ☒ is attached hereto.

☐ and is amended by the Preliminary Amendment attached hereto.

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I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

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Provisional Application Number	Filing Date
60/165,882	November 16, 1999

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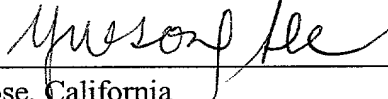
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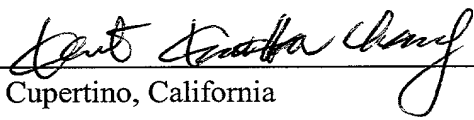
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